Strain relaxation study in high Indium content metamorphic InGaAs/InAlAs modulation doped heterostructures

Shin-ichiro Gozu, Tomohiro Kita, Hidetaka Sato and Syoji Yamada
School of Materials Science, JAIST,
1-1, Asahidai, Tatsunokuti, Ishikawa, 923-1292 Japan
gozu@jaist.ac.jp

Recently metamorphic growth technique has been studied extensively [1] in molecular beam epitaxy . The features are the freedom in choosing substrate and alloy composition. Therefore, this technique is one of the suitable growth methods for industrial production of (opt-) electronic devices. On the other hand, metamorphic modulation doped heterostructures (MDH) have recently found an application to new concept devices such as spin- and/or Josephson- FETs, which have been proposed in very recent years. However, the electronic qualities are not sufficient for such applications, since they need high electron mobilities (long mean-free-path) as well as low contact resistances at ferromagnetic/superconductive electrodes. To overcome these problems, we have proposed [2] high Indium content metamorphic InGaAs/InAlAs MDHs grown on GaAs substrates. Nevertheless, metamorphic growth has a weak point such as an amount of residual strain, in general. To solve the problem, the use of advanced strain relaxation layer, so-called inverse step (IS), was proposed by Sacedom et al [3]. In this paper, we report the results of applying the advanced strain relaxation layer structure to the growth of MDHs in terms of electronic properties and photoluminescence spectra.

The structures were prepared by conventional solid-source MBE system. Step graded buffer (SGB) [2] (+IS [3]) was adopted as strain relaxation layer. SGB, IS-SGB and MDH layer structures adopted here are shown in Fig. 1. IS strain relaxation layer concepts consider equivalent (in-plane) lattice constant which reflects residual strain. Therefore, IS-SGB layer had Indium content in InAlAs of +5% from designed Indium content. All Indium contents were determined from RHEED oscillation relations for the growth of GaAs, AlAs and InAs layers. Electrical properties were investigated by Hall measurement using conventional Van der Pauw method at RT and 77K. PL measurements performed in a optical He cryostat. Figure 2 shows PL results of 300nm InGaAs on (IS) - SGB samples with Indium content from PL peak calculation. Red shift of PL peak in case 4 from that in case 2 was observed. It is well known that if compressive strain increases, band edge energy increases. Therefore, case 2 sample has a larger compressive strain force which might be originated from the residual strain from SGB layer than that in case 4 sample. Thus, the residual strain was decreased with last layer Indium content and thickness. Figure 3 shows 77K Hall measurement results. Except the mobility for the case 2, electron mobility has a tendency to increase with the decreasing residual strain. The case 2 sample has a relatively high background impurity, since it has been grown just after the MBE system opening. Since all samples have same MDH structures and almost equal N_s, other mechanisms which suppress the mobility should be same. We thus believe that the residual strain is one of the important interface condition which determines the low temperature (77K) electron mobility in those MDHs.

[1] For example, K. Inoue, J. C. Harmond and T. Matsuo, J. Cryst. Growth **111**(1991)313

E. A. Fitzgerald, Y. H. Xie, D. Monroe, P. J. Sliverman, J. M. Kuo, A. R. Kortan, F. A. Thiel and B. E. Weir, J. Vac. Sci. Technol, **B10** (1992)1807

T. Mishima, K. Higuchi, M. Mori and M. Kudo, J. Cryst. Growth **150**(1995)1230

[2] S. Gozu, C. Hong and S. Yamada, Jpn. J. Appl. Phys. **L37**(1998) 1501

[3] A. Sacedom, F. Gonzalez-Sanz, E. Calleja, E. Munōz, S. I. Molina: Appl. Phys. Lett. **66**(1995)3334

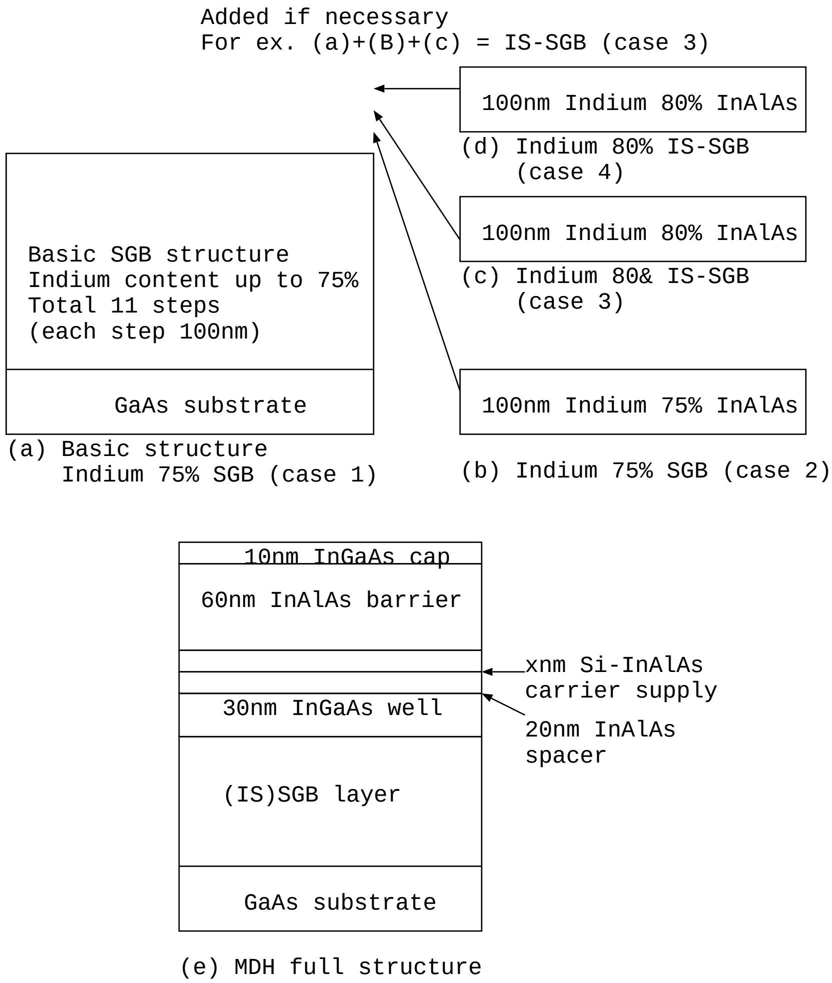

Figure 1: Strain relaxation layer and MDH structures

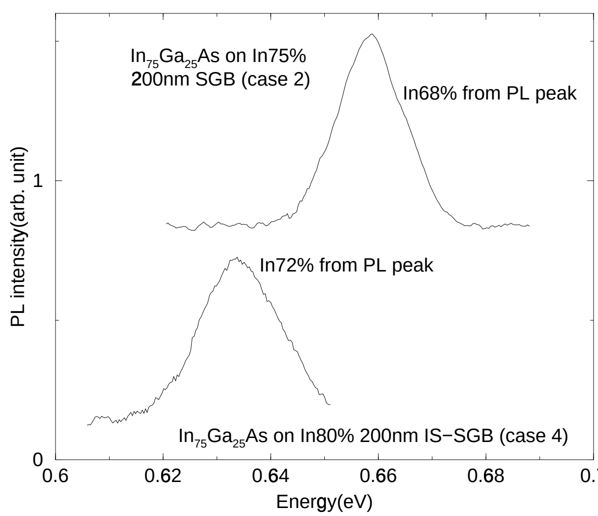

Figure 2: PL measurement results of InGaAs 300nm on (IS)SGBs

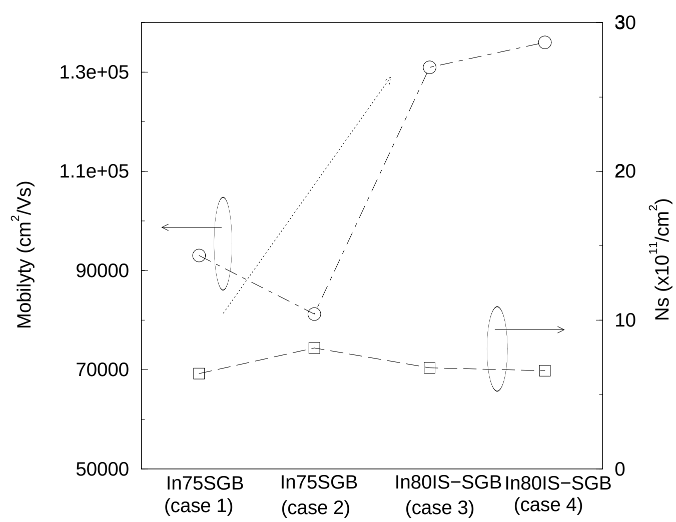

Figure 3: Hall measurement results at 77K